T-mobile personal cellspot lte signal booster

Small, low-power cellular base station In telecommunications, a femtocell is a small, low-power cellular base station, typically designed for use in a home or small business. A broader term which is more widespread in the industry is small cell, with femtocell as a subset. It connects to the service provider's network via broadband (such as DSL or cable); current designs typically support four to eight simultaneously active mobile phones in a residential setting depending on version number and femtocell hardware, and eight to sixteen mobile phones in enterprise settings. A femtocell allows service providers to extend service coverage indoors or at the cell edge, especially where access would otherwise be limited or unavailable. Although much attention is focused on WCDMA, the concept is applicable to all standards, including GSM, CDMA2000, TD-SCDMA, WiMAX and LTE solutions. Verizon and AT&T femtocell access points The use of femtocells allows network coverage in places where the signal to the main network cells might be too weak. Furthermore, femtocells lower contention on the main network cells, by forming a connection from the end user, through an internet connection, to the operator's private network infrastructure elsewhere. The lowering of contention to the main cells plays a part in breathing, where connections are offloaded based on physical distance to cell towers. Consumers and small businesses benefit from greatly improved coverage and signal strength since they have a de facto base station inside their premises. As a result of being relatively close to the femtocell, the mobile phone (user equipment) expends significantly less power for communication with it, thus increasing battery life. They may also get better voice quality (via HD voice) depending on a number of factors such as operator/network support, customer contract/price plan, phone and operating system support. Some carriers may also offer more attractive tariffs, for example discounted calls from home. Femtocells are an alternative way to deliver the benefits of fixed–mobile convergence (FMC). The distinction is that most FMC architectures require a new dual-mode handset which works with existing unlicensed spectrum home/enterprise wireless access points, while a femtocell-based deployment will work with existing handsets but requires the installation of a new access point that uses licensed spectrum. Many operators worldwide offer a femtocell service, mainly targeted at businesses but also offered to individual customers (often for a one-off fee) when they complain to the operator regarding a poor or non-existent signal at their location. Operators who have launched a femtocell service include SFR, AT&T, C Spire, Sprint Nextel, Verizon, Zain, Mobile TeleSystems, T-Mobile US, Orange, Vodafone, EE, O2, Three, and others. In 3GPP terminology, a Home NodeB (HNB) is a 3G femtocell. A Home eNodeB (HeNB) is an LTE 4G femtocell. Theoretically the range of a standard base station may be up to 35 kilometres (22 mi), and in practice could be 5–10 km (3–6 mi), a microcell is less than two kilometers wide, a picocell is 200 meters or less, and a femtocell is in the order of 10 meters,[1] although AT&T calls its product, with a range of 40 feet (12 m), a "microcell".[2] AT&T uses "AT&T 3G MicroCell" as a trademark and not necessarily the "microcell" technology, however.[3] Overview and benefits Operating mode Femtocells are sold or loaned by a mobile network operator (MNO) to its residential or enterprise customers. A femtocell is typically the size of a residential gateway or smaller, and connects to the user's broadband line. Integrated femtocells (which include both a DSL router and femtocell) also exist. Once plugged in, the femtocell connects to the MNO's mobile network, and provides extra coverage. From a user's perspective, it is plug and play, there is no specific installation or technical knowledge required—anyone can install a femtocell at home. In most cases,[4] the user must then declare which mobile phone numbers are allowed to connect to their femtocell, usually via a web interface provided by the MNO.[5] This needs to be done only once. When these mobile phones arrive under coverage of the femtocell, they switch over from the macrocell (outdoor) to the femtocell automatically. Most MNOs provide a way for the user to know this has happened, for example by having a different network name appear on the mobile phone. All communications will then automatically go through the femtocell. When the user leaves the femtocell coverage (whether in a call or not) area, their phone hands over seamlessly to the macro network. Femtocells require specific hardware, so existing WiFi or DSL routers cannot be upgraded to a femtocell. Once installed in a specific location, most femtocells have protection mechanisms so that a location change will be reported to the MNO. Whether the MNO allows femtocells to operate in a different location depends on the MNO's policy. International location change of a femtocell is not permitted because the femtocell transmits licensed frequencies which belong to different network operators in different countries. Benefits for users The main benefits for an end user are the following: "5 bar" coverage when there is no existing signal or poor coverage Higher mobile data capacity, which is important if the end-user makes use of mobile data on their mobile phone (may not be relevant to a large number of subscribers who instead use WiFi where femtocell is located) Depending on the pricing policy of the MNO, special tariffs at home can be applied for calls placed under femtocell coverage For enterprise users, having femtos instead of DECT ("cordless" home) phones enables them to have a single phone, so a single contact list, etc. Improved battery life for mobile devices due to reduced transmitter–receiver distance The battery draining issue of mobile operators can be eliminated by means of energy efficiency of the networks resulting in prolongation of the battery life of handsets[6] New applications and services can be created to enhance user experience or provide additional features: In Connected car case the use of Femtocells has been proposed as a safety feature (c.f. patent application EP2647257B1 by Valentin A. Alexeev[7]) Femtocells can be used to give coverage in rural areas. Standardised architectures Simplified version of traditional Node B and Home Node B (3G femtocell) in 3G architecture The standards bodies have published formal specifications for femtocells for the most popular technologies, namely WCDMA, CDMA2000, LTE and WiMAX. These all broadly conform to an architecture with three major elements: The femtocell access points themselves, which embody greater network functionality than found in macrocell basestations, such as the radio resource control functions. This allows much greater autonomy within the femtocell, enabling self-configuration and self-optimisation. Femtocells are connected using broadband IP, such as DSL or cable modems, to the network operator's core switching centres. The femtocell gateway, comprising a security gateway that terminates large numbers of encrypted IP data connections from hundreds of thousands of femtocells, and a signalling gateway which aggregates and validates the signalling traffic, authenticates each femtocell and interfaces with the mobile network core switches using standard protocols, such as Iuh[expand acronym]. The management and operational system which allows software updates and diagnostic checks to be administered. These typically use the same TR-069 management protocol published by the Broadband Forum and also used for administration of residential modems. The key interface in these architectures is that between the femtocell access points and the femtocell gateway. Standardisation enables a wider choice of femtocell products to be used with any gateway, increasing competitive pressure and driving costs down. For the common WCDMA femtocells, this is defined as the Iuh[expand acronym] interface. In the Iuh architecture, the femtocell gateway sits between the femtocell and the core network and performs the necessary translations to ensure the femtocells appear as a radio network controller to existing mobile switching centres (MSCs). Each femtocell talks to the femtocell gateway and femtocell gateways talk to the Core Network Elements (CNE) (MSC for circuit-switched calls, SGSN for packet-switched calls). This model was proposed by 3GPP and the Femto Forum.[8] New protocols (HNBAP [Home Node B Application Part] and RUA[9] [RANAP User Adaptation]) have been derived; HNBAP is used for the control signaling between the HNB and HNB-GW[10] while RUA[9] is a lightweight mechanism to replace the SCCP[expand acronym] and M3UA[expand acronym] protocols in the RNC[expand acronym]; its primary function is transparent transfer of RANAP[expand acronym] messages.[11] In March 2010, the Femto Forum and ETSI conducted the first Plugfest to promote interoperability of the Iuh standard.[12] The CDMA2000 standard released in March 2010[13] differs slightly by adopting the Session Initiation Protocol (SIP) to set up a connection between the femtocell and a femtocell convergence server (FCS). Voice calls are routed through the FCS which emulates an MSC. SIP is not required or used by the mobile device itself. In the SIP architecture, the femtocell connects to a core network of the mobile operator that is based on the SIP/IMS architecture. This is achieved by having the femtocells behave toward the SIP/IMS network like a SIP/IMS client by converting the circuit-switched 3G signaling to SIP/IMS signaling, and by transporting the voice traffic over RTP as defined in the IETF standards. Air interfaces Although much of the commercial focus seems to have been on the Universal Mobile Telecommunications System (UMTS), the concept is equally applicable to all air-interfaces. Indeed, the first commercial deployment was the CDMA2000 Airave in 2007 by Sprint. Femtocells are also under development or commercially available for GSM, TD-SCDMA, WiMAX and LTE. The H(e)NB functionality and interfaces are basically the same as for regular High Speed Packet Access (HSPA) or LTE base stations except few additional functions. The differences are mostly to support differences in access control to support closed access for residential deployment or open access for enterprise deployment, as well as handover functionality for active subscribers and cell selection procedures for idle subscribers. For LTE additional functionality was added in 3GPP Release 9 which is summarized in.[14] Issues Interference The placement of a femtocell has a critical effect on the performance of the wider network, and this is the key issue to be addressed for successful deployment. Because femtocells can use the same frequency bands as the conventional cellular network, there has been the worry that rather than improving the situation they could potentially cause problems. Femtocells incorporate interference mitigation techniques—detecting macrocells, adjusting power[15] and scrambling codes accordingly. Ralph de la Vega, AT&T President, reported in June 2011 they recommended against using femtocells where signal strength was middle or strong because of interference problems they discovered after widescale deployment.[16] This differs from previous opinions expressed by AT&T and others. A good example is the comments made by Gordon Mansfield, Executive Director of RAN Delivery, AT&T, speaking at the Femtozone at CTIA March 2010: We have deployed femtocells co-carrier with both the hopping channels for GSM macrocells and with UMTS macrocells. Interference isn’t a problem. We have tested femtocells extensively in real customer deployments of many thousands of femtocells, and we find that the mitigation techniques implemented successfully minimise and avoid interference. The more femtocells you deploy, the more uplink interference is reduced. The Femto Forum has some extensive reports on this subject, which have been produced together with 3GPP and 3GPP2.[17][18] To quote from the Summary Paper — Summary of Findings: The simulations performed in the Femto Forum WG2 and 3GPP RAN4 encompass a wide spectrum of possible deployment scenarios including shared channel and dedicated channel deployments. In addition, the studies looked at the impact in different morphologies, as well as in closed versus open access. The following are broad conclusions from the studies: 1. When femtocells are used in areas of poor or no coverage, macro/femto interference is unlikely to be a problem. 2. If the femto network is sharing the channel (co-channel) with the macro network, interference can occur. However, if the interference management techniques advocated by the Femto Forum are adopted, the resulting interference can be mitigated in most cases. 3. A femtocell network deployed on an adjacent dedicated channel is unlikely to create interference to a macro network. Additionally, the impact of a macro network on the performance of a femtocell on an adjacent channel is limited to isolated cases. If the interference mitigation techniques advocated by the Femto Forum are used, the impact is further marginalised. 4. Closed access represents the worst-case scenario for creation of interference. Open access reduces the chances of User Equipment (mobile phone handsets, 3G data dongles, etc.) on the macro network interfering with a proximate femtocell. 5. The same conclusions were reached for both the 850 MHz (3GPP Band 17) and 2100 MHz (3GPP Band 1) deployments that were studied. The conclusions are common to the 850 MHz and 2100 MHz bands that were simulated in the studies, and can be extrapolated to other mobile bands. With interference mitigation techniques successfully implemented, simulations show that femtocell deployments can enable very high capacity networks by providing between a 10 and 100 times increase in capacity with minimal deadzone impact and acceptable noise rise. Femtocells can also create a much better user experience by enabling substantially higher data rates than can be obtained with a macro network and net throughputs that will be ultimately limited by backhaul in most cases (over 20 Mbps in 5 MHz). Lawful interception Access point base stations, in common with all other public communications systems, are required to comply with lawful interception requirements in most countries. Equipment location Other regulatory issues[19] relate to the requirement in most countries for the operator of a network to be able to show exactly where each base-station is located, and for E911 requirements to provide the registered location of the equipment to the emergency services. There are issues in this regard for access point base stations sold to consumers for home installation, for example. Further, a consumer might try to carry their base station with them to a country where it is not licensed. Some manufacturers are using GPS within the equipment to lock the femtocell when it is moved to a different country;[20] this approach is disputed[citation needed], as GPS is often unable to obtain position indoors because of weak signal. Emergency calls Access Point Base Stations are also required, since carrying voice calls, to provide a 911 (or 999, 112, etc.) emergency service, as is the case for VoIP phone providers in some jurisdictions.[19] This service must meet the same requirements for availability as current wired telephone systems, such as functioning during a power failure. There are several ways to achieve this, such as alternative power sources or fallback to existing telephone infrastructure. Quality of service When using an Ethernet or ADSL home backhaul connection, an Access Point Base Station must either share the backhaul bandwidth with other services, such as Internet browsing, gaming consoles, set-top boxes and triple-play equipment in general, or alternatively directly replace these functions within an integrated unit. In shared-bandwidth approaches, which are the majority of designs currently being developed, the effect on quality of service may be an issue. The uptake of femtocell services will depend on the reliability and quality of both the cellular operator's network and the third-party broadband connection, and the broadband connection's subscriber understanding the concept of bandwidth utilization by different applications a subscriber may use. When things go wrong, subscribers will turn to cellular operators for support even if the root cause of the problem lies with the broadband connection to the home or workplace. Hence, the effects of any third-party ISP broadband network issues or traffic management policies need to be very closely monitored and the ramifications quickly communicated to subscribers. A key issue recently identified is active traffic shaping by many ISPs on the underlying transport protocol IPSec.[citation needed] Spectrum accuracy To meet Federal Communications Commission (FCC) / Ofcom spectrum mask requirements, femtocells must generate the radio frequency signal with a high degree of precision. To do this over a long period of time is a major technical challenge. The solution to this problem is to use an external, accurate signal to constantly calibrate the oscillator to ensure it maintains its accuracy. This is not simple (broadband backhaul introduces issues of network jitter/wander and recovered clock accuracy), but technologies such as the IEEE 1588 time synchronisation standard may address the issue. Also, Network Time Protocol (NTP) is being pursued by some developers as a possible solution to provide frequency stability. Conventional (macrocell) base stations often use GPS timing for synchronization and this could be used,[20] although there are concerns on cost and the difficulty of ensuring good GPS coverage. Standards bodies have recognized the challenge of this and the implications on device cost. For example, 3GPP has relaxed the 50ppb parts per billion precision to 100ppb for indoor base stations in Release 6 and a further loosening to 250ppb for Home Node B in Release 8. Security At the 2013 Black Hat hacker conference in Las Vegas, NV, a trio of security researchers detailed their ability to use a Verizon femtocell to secretly intercept the voice calls, data, and SMS text messages of any handset that connects to the device. During a demonstration of their exploit, they showed how they could begin recording audio from a cell phone even before the call began. The recording included both sides of the conversation. They also demonstrated how it could trick Apple's iMessage–which encrypts texts sent over its network using SSL to render them unreadable to snoopers, to SMS—allowing the femtocell to intercept the messages. They also demonstrated it was possible to "clone" a cell phone that runs on a CDMA network by remotely collecting its device ID number through the femtocell, in spite of added security measures to prevent against cloning of CDMA phones.[21] Controversy on consumer proposition The impact of a femtocell is most often to improve cellular coverage, without the cellular carrier needing to improve their infrastructure (cell towers, etc.). This is net gain for the cellular carrier. However, the user must provide and pay for an internet connection to route the femtocell traffic, and then (usually) pay an additional one-off or monthly fee to the cellular carrier. Some have objected to the idea that consumers are being asked to pay to help relieve network shortcomings.[22] On the other hand, residential femtocells normally provide a ‘personal cell’ which provides benefits only to the owner's family and friends.[23] The difference is also that while mobile coverage is provided through subscriptions from an operator with one business model, a fixed fibre or cable may work with a completely different business model. For example, mobile operators may imply restrictions on services which an operator on a fixed may not. Also, WiFi connects to a local network such as home servers and media players. This network should possibly not be within reach of the mobile operator. Deployment According to market research firm Informa and the Femto Forum,[24] as of December 2010 18 operators have launched commercial femtocell services, with a total of 30 committed to deployment. At the end of 2011, femtocell shipments had reached roughly 2 million units deployed annually, and the market is expected to grow rapidly with distinct segments for consumer, enterprise, and carrier-grade femtocell deployments.[25] Femtocell shipments are estimated to have reached almost 2 million at the end of 2010.[26] Research firm Berg Insight estimates that the shipments will grow to 12 million units worldwide in 2014.[27] Within the United States, Cellcom (Wisconsin), was the first CDMA carrier in the U.S. to be a member of the non-profit organization founded in 2007 to promote worldwide femtocell deployment. In 2009, Cellcom received the first Femtocell Industry Award for significant progress or commercial launch by a small carrier at the Femtocells World Summit in London. Additional significant deployments within the United States were by Sprint Nextel, Verizon Wireless and AT&T Wireless. Sprint started in the third quarter of 2007 as a limited rollout (Denver and Indianapolis) of a home-based femtocell built by Samsung Electronics called the Sprint Airave that works with any Sprint handset.[28] From 17 August 2008, the Airave was rolled out on a nationwide basis. Other operators in the United States have followed suit. In January 2009, Verizon rolled out its Wireless Network Extender, based on the same design as the Sprint/Samsung system.[29] In late March 2010, AT&T announced nationwide roll-out of its 3G MicroCell, which commenced in April. The equipment is made by Cisco Systems and ip.access, and was the first 3G femtocell in US, supporting both voice and data HSPA.[30] Both Sprint[31] and Verizon[32] upgraded to 3G CDMA femtocells during 2010, with capacity for more concurrent calls and much higher data rates. In November 2015, T-Mobile US began deployment of 4G LTE femtocells manufactured by Alcatel Lucent. In Asia, several service providers have rolled out femtocell networks. In Japan, SoftBank launched its residential 3G femtocell service in January 2009[33] with devices provided by Ubiquisys. In the same year, the operator launched a project to deploy femtocells to deliver outdoor services in rural environments where existing coverage is limited. In May 2010, SoftBank Mobile launched the first free femtocell offer, providing open access femtocells free of charge to its residential and business customers. In Singapore, Starhub rolled out its first nationwide commercial 3G femtocell services with devices provided by Huawei Technologies, though the uptake is low, while Singtel's offering is targeted at small medium enterprises. In 2009, China Unicom announced its own femtocell network.[34] NTT DoCoMo in Japan launched their own femtocell service on 10 November 2009. In July 2009, Vodafone released the first femtocell network in Europe,[35] the Vodafone Access Gateway provided by Alcatel-Lucent.[36] This was rebranded as SureSignal in January 2010,[37] after which Vodafone also launched service in Spain, Greece, New Zealand,[38][39] Italy, Ireland,[40] Hungary[41] and The Netherlands.[42] Other operators in Europe have followed since then. Operator Country Launch date Note Cellcom United States of America March 2007 Sprint United States of America September 2007 provided by Samsung,[28] Airvana (now CommScope) [43] StarHub Singapore November 2008 provided by Huawei[44] SoftBank Japan January 2009 provided by Ubiquisys Verizon Wireless United States of America January 2009 [44] TDC Denmark April 2009 provided by Ubiquisys[45] Vodafone United Kingdom July 2009 AT&T United States of America September 2009 [44] China Unicom China November 2009 [44] NTT DoCoMo Japan November 2009 SFR France November 2009 provided by Ubiquisys[46] Retired at the beginning of 2019[47] NOS Portugal December 2009 [48] SingTel Singapore January 2010 [49] Vodafone Spain June 2010 KDDI Japan July 2010 [44] Vodafone Greece July 2010 Movistar Spain August 2010 [44] T-Mobile United Kingdom October 2010 [44] Moldtelecom Moldova November 2010 [44] Vodafone New Zealand January 2011 Vodafone Ireland February 2011 Network Norway Norway February 2011 provided by NEC[50] Optus Australia April 2011 [44] Vodafone Australia May 2011 [44] MegaFon Russia May 2011 [44] Vodafone Italy May 2011 Vodafone Hungary May 2011 Orange France May 2011 Retired in September 2021[51] [44] Orange Romania May 2011 [44] MTS Russia May 2011 [44] Vodafone Czech Republic July 2011 [44] Beeline Russia August 2011 [44] Vodafone The Netherlands October 2011 Cosmote Greece October 2011 [44] Vodafone Portugal January 2012 [44] Mosaic Telecom United States of America February 2012 [44] Free France February 2012 In progress of retirement as from September 2021[52][44] 3 United Kingdom February 2012 [44] Zain Bahrain May 2012 [44] Vodafone Germany August 2012 provided by Huawei[53] Globe Philippines December 2012 provided by NEC, Nextivity & ip.access O2 Germany May 2013 provided by Alcatel-Lucent[54] M1 Singapore May 2013 provided by Alcatel-Lucent[55] Orange Poland January 2014 Sunrise Switzerland February 2014 provided by NEC[56] Salt Switzerland April 2014 provided by Nokia[57] Maxis Malaysia April 2014 provided by Alcatel-Lucent.[58] DiGi Malaysia January 2015 Planned to launch Femtocell in 2014.[59] AIS Thailand January 2015 provided by Alcatel-Lucent dtac Thailand January 2015 provided by Alcatel-Lucent Swisscom Switzerland June 2015 provided by Cisco[60] MTS Belarus June 2015 provided by Cisco[61] T-Mobile United States of America November 2015 provided by Alcatel-Lucent Celcom Malaysia June 2016 Planned to launch Femtocell in 2016.[62] Jio India July 2016 Retirement From 2019 onwards, all 3 French carriers still proposing Femtocell retired their offering, focusing instead on using the Voice Over Wifi technology when a better 3G/4G covering is unpractical to deploy See also 5G Cellular repeater T-Mobile 4G LTE CellSpot References ^ Dimitris Mavrakis (2007-12-01). 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Ref. 8 can be found at : a new release exists : Retrieved from " 2Broadband cellular network standard (2016) For other uses, see 5G (disambiguation). 5G3GPP's 5G logoDeveloped by3GPPIntroducedJuly 2016 (July 2016)IndustryTelecommunications Part of a series on theMobile phone generations Mobile telecommunications Analog 0G 1G Digital 2G 2.5G 2.75G 3G 3.5G 3.75G 3.9G/3.95G 4G 4G/4.5G 4.5G/4.9G 5G 6G vte In telecommunications, 5G is the fifth-generation technology standard for broadband cellular networks, which cellular phone companies began deploying worldwide in 2019, and is the planned successor to the 4G networks which provide connectivity to most current cellphones. 5G networks are predicted to have more than 1.7 billion subscribers worldwide by 2025, according to the GSM Association.[1] Like its predecessors, 5G networks are cellular networks, in which the service area is divided into small geographical areas called cells. All 5G wireless devices in a cell are connected to the Internet and telephone network by radio waves through a local antenna in the cell. The main advantage of the new networks is that they will have greater bandwidth, giving higher download speeds, eventually up to 10 gigabits per second (Gbit/s).[2] In addition to 5G being faster than existing networks, 5G has higher bandwidth and can thus connect more different devices, improving the quality of Internet services in crowded areas.[3] Due to the increased bandwidth, it is expected the networks will increasingly be used as general internet service providers (ISPs) for laptops and desktop computers, competing with existing ISPs such as cable internet, and also will make possible new applications in internet-of-things (IoT) and machine-to-machine areas. Cellphones with 4G capability alone are not able to use the new networks, which require 5G-enabled wireless devices. Overview 5G networks are cellular networks, in which the service area is divided into small geographical areas called cells. All 5G wireless devices in a cell communicate by radio waves with a cellular base station via fixed antennas, over frequency channels assigned by the base station. The base stations, termed gNodeBs, are connected to switching centers in the telephone network and routers for Internet access by high-bandwidth optical fiber or wireless backhaul connections. As in other cellular networks, a mobile device moving from one cell to another is automatically handed off seamlessly to the current cell. 5G can support up to a million devices per square kilometer, while 4G supports only one-tenth of that capacity.[citation needed] Several network operators use millimeter waves called FR2 in 5G terminology, for additional capacity and higher throughputs. Millimeter waves have a shorter range than microwaves, therefore the cells are limited to a smaller size. Millimeter waves also have more trouble passing through building walls. Millimeter-wave antennas are smaller than the large antennas used in previous cellular networks. Some are only a few centimeters long. The increased speed is achieved partly by using additional higher-frequency radio waves in addition to the low- and medium-band frequencies used in previous cellular networks. However, higher-frequency radio waves have a shorter useful physical range, requiring smaller geographic cells. For wide service, 5G networks operate on up to three frequency bands – low, medium, and high. 5G can be implemented in low-band, mid-band or high-band millimeter-wave 24 GHz up to 54 GHz. Low-band 5G uses a similar frequency range to 4G cellphones, 600–900 MHz, giving download speeds a little higher than 4G: 30–250 megabits per second (Mbit/s).[4] Low-band cell towers have a range and coverage area similar to 4G towers. Mid-band 5G uses microwaves of 1.7–4.7 GHz, allowing speeds of 100–900 Mbit/s, with each cell tower providing service up to several kilometers in radius. This level of service is the most widely deployed, and was deployed in many metropolitan areas in 2020. Some regions are not implementing the low band, making Mid-band the minimum service level. High-band 5G uses frequencies of 24–47 GHz, near the bottom of the millimeter wave band, although higher frequencies may be used in the future. It often achieves download speeds in the gigabit-per-second (Gbit/s) range, comparable to cable internet. However, millimeter waves (mmWave or mmW) have a more limited range, requiring many small cells.[5] They can be impeded or blocked by materials in walls or windows.[6] Due to their higher cost, plans are to deploy these cells only in dense urban environments and areas where crowds of people congregate such as sports stadiums and convention centers. The above speeds are those achieved in actual tests in 2020, and speeds are expected to increase during rollout.[4] The spectrum ranging from 24.25–29.5 GHz has been the most licensed and deployed 5G mmWave spectrum range in the world.[citation needed] The industry consortium setting standards for 5G is the 3rd Generation Partnership Project (3GPP). It defines any system using 5G NR (5G New Radio) software as "5G", a definition that came into general use by late 2018. Minimum standards are set by the International Telecommunication Union (ITU). Rollout of 5G technology has led to debate over its security and relationship with Chinese vendors. It has also been the subject of health concerns and misinformation, including discredited conspiracy theories linking it to the COVID-19 pandemic. Application areas The ITU-R has defined three main application areas for the enhanced capabilities of 5G. They are Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), and Massive Machine Type Communications (mMTC).[7] Only eMBB is deployed in 2020; URLLC and mMTC are several years away in most locations.[8] Enhanced Mobile Broadband (eMBB) uses 5G as a progression from 4G LTE mobile broadband services, with faster connections, higher throughput, and more capacity. This will benefit areas of higher traffic such as stadiums, cities, and concert venues.[9] Ultra-Reliable Low-Latency Communications (URLLC) refer to using the network for mission critical applications that require uninterrupted and robust data exchange. The short-packet data transmission is used to meet both reliability and latency requirements of the wireless communication networks. Massive Machine-Type Communications (mMTC) would be used to connect to a large number of devices. 5G technology will connect some of the 50 billion connected IoT devices.[10] Most will use the less expensive Wi-Fi. Drones, transmitting via 4G or 5G, will aid in disaster recovery efforts, providing real-time data for emergency responders.[10] Most cars will have a 4G or 5G cellular connection for many services. Autonomous cars do not require 5G, as they have to be able to operate where they do not have a network connection.[11] However, most autonomous vehicles also feature teleoperations for mission accomplishment, and these greatly benefit from 5G technology.[12][13] Performance This article possibly contains unsourced predictions, speculative material, or accounts of events that might not occur. Information must be verifiable and based on reliable published sources. Please help improve it by removing unsourced speculative content. (January 2022) (Learn how and when to remove this template message) Speed 5G speeds will range from ~50 Mbit/s to over 1,000 Mbit/s (1 Gbit/s). The fastest 5G speeds would be in the mmWave bands and can reach 4 Gbit/s with carrier aggregation and MIMO. Sub-6 GHz 5G (mid-band 5G), by far the most common, will usually deliver between 100 and 1,400 MBit/s but will have a much further reach than mmWave, especially outdoors. C-Band (n77/n78) will be deployed by various U.S. operators in 2022. C-Band had been planned to be deployed by Verizon and AT&T in early January 2022 but was delayed due to safety concerns raised by the Federal Aviation Administration.[14][15] The Low-band spectrum offers the greatest range, thereby a greater coverage area for a given site, but its speeds are lower than the mid and high bands. Latency In 5G, the "air latency" is of the order of 8–12 milliseconds. The latency to the server must be added to the "air latency" for most comparisons. Verizon reported the latency on its 5G early deployment is 30 ms: Edge Servers close to the towers can reduce latency to 10–20 ms; 1–4 ms will be extremely rare for years outside the lab. The latency is much higher during handovers; ranging from 50–500 milliseconds depending on the type of handover. Reducing handover latency is an ongoing area of research and development. Error rate 5G uses adaptive modulation and coding scheme (MCS) to keep the bit error rate extremely low. Whenever the error rate crosses a (very low) threshold the transmitter will switch to a lower MCS, which will be less error-prone. This way speed is sacrificed to ensure an almost zero error rate. Range The range of 5G depends on many factors; frequency is the most important of all. mmWave signals tend to have a range of only a couple of hundred meters whilst low band signals generally have a range of a couple of kilometers. Since there is a lot of marketing hype on what 5G can offer, simulators and drive tests are used for the precise measurement of 5G performance. Standards Initially, the term was associated with the International Telecommunication Union's IMT-2020 standard, which required a theoretical peak download speed of 20 gigabits per second and 10 gigabits per second upload speed, along with other requirements.[16] Then, the industry standards group 3GPP chose the 5G NR (New Radio) standard together with LTE as their proposal for submission to the IMT-2020 standard.[17][18] 5G NR can include lower frequencies (FR1), below 6 GHz, and higher frequencies (FR2), above 24 GHz. However, the speed and latency in early FR1 deployments, using 5G NR software on 4G hardware (non-standalone), are only slightly better than new 4G systems, estimated at 15 to 50% better.[19][20][21] The standard documents for 5G are organized by 3GPP.[22][23] The 5G system architecture is defined in TS 23.501.[24] The packet protocol for mobility management (establishing connection and moving between base stations) and session management (connecting to networks and network slices) is described in TS 24.501.[25] Specifications of key data structures are found in TS 23.003.[26] Fronthaul network IEEE covers several areas of 5G with a core focus in wireline sections between the Remote Radio Head (RRH) and Base Band Unit (BBU). The 1914.1 standards focus on network architecture and dividing the connection between the RRU and BBU into two key sections. Radio Unit (RU) to the Distributor Unit (DU) being the NGFI-I (Next Generation Fronthaul Interface) and the DU to the Central Unit (CU) being the NGFI-II interface allowing a more diverse and cost-effective network. NGFI-I and NGFI-II have defined performance values which should be compiled to ensure different traffic types defined by the ITU are capable of being carried.[page needed] The IEEE 1914.3 standard is creating a new Ethernet frame format capable of carrying IQ data in a much more efficient way depending on the functional split utilized. This is based on the 3GPP definition of functional splits.[page needed] 5G NR Main article: 5G NR 5G NR (New Radio) is a new air interface developed for the 5G network.[27] It is supposed to be the global standard for the air interface of 3GPP 5G networks.[28] Pre-standard implementations 5GTF: The 5G network implemented by American carrier Verizon for Fixed Wireless Access in late 2010s uses a pre-standard specification known as 5GTF (Verizon 5G Technical Forum). The 5G service provided to customers in this standard is incompatible with 5G NR. There are plans to upgrade 5GTF to 5G NR "Once [it] meets our strict specifications for our customers," according to Verizon.[29][needs update?] 5G-SIG: Pre-standard specification of 5G developed by KT Corporation. Deployed at Pyeongchang 2018 Winter Olympics.[30] Internet of things In the Internet of things (IoT), 3GPP is going to submit evolution of NB-IoT and eMTC (LTE-M) as 5G technologies for the LPWA (Low Power Wide Area) use case.[31] Deployment See also: List of 5G NR networks 5G 3.5 GHz cell site of Deutsche Telekom in Darmstadt, Germany 5G 3.5 GHz cell site of Vodafone in Karlsruhe, Germany Beyond mobile operator networks, 5G is also expected to be used for private networks with applications in industrial IoT, enterprise networking, and critical communications, in what being described as NR-U (5G NR in Unlicensed Spectrum)[32] Initial 5G NR launches depended on pairing with existing LTE (4G) infrastructure in non-standalone (NSA) mode (5G NR radio with 4G core), before maturation of the standalone (SA) mode with the 5G core network.[33] As of April 2019, the Global Mobile Suppliers Association had identified 224 operators in 88 countries that have demonstrated, are testing or trialing, or have been licensed to conduct field trials of 5G technologies, are deploying 5G networks or have announced service launches.[34] The equivalent numbers in November 2018 were 192 operators in 81 countries.[35] The first country to adopt 5G on a large scale was South Korea, in April 2019. Swedish telecoms giant Ericsson predicted that 5G internet will cover up to 65% of the world's population by the end of 2025.[36] Also, it plans to invest 1 billion reals ($238.30 million) in Brazil to add a new assembly line dedicated to fifth-generation technology (5G) for its Latin American operations.[37] When South Korea launched its 5G network, all carriers used Samsung, Ericsson, and Nokia base stations and equipment, except for LG U Plus, who also used Huawei equipment.[38][39] Samsung was the largest supplier for 5G base stations in South Korea at launch, having shipped 53,000 base stations at the time, out of 86,000 base stations installed across the country at the time.[40] The first fairly substantial deployments were in April 2019. In South Korea, SK Telecom claimed 38,000 base stations, KT Corporation 30,000 and LG U Plus 18,000; of which 85% are in six major cities.[41] They are using 3.5 GHz (sub-6) spectrum in non-standalone (NSA) mode and tested speeds were from 193 to 430 Mbit/s down.[42] 260,000 signed up in the first month and 4.7 million by the end of 2019.[43] T-Mobile US was the 1st company in the world to launch a commercially available 5G NR Standalone network.[44] Nine companies sell 5G radio hardware and 5G systems for carriers: Altiostar, Cisco Systems, Datang Telecom/Fiberhome, Ericsson, Huawei, Nokia, Qualcomm, Samsung, and ZTE.[45][46][47][48][49][50][51] Spectrum Large quantities of new radio spectrum (5G NR frequency bands) have been allocated to 5G.[52] For example, in July 2016, the U.S. Federal Communications Commission (FCC) freed up vast amounts of bandwidth in underused high-band spectrum for 5G. The Spectrum Frontiers Proposal (SFP) doubled the amount of millimeter-wave unlicensed spectrum to 14 GHz and created four times the amount of flexible, mobile-use spectrum the FCC had licensed to date.[53] In March 2018, European Union lawmakers agreed to open up the 3.6 and 26 GHz bands by 2020.[54] As of March 2019[update], there are reportedly 52 countries, territories, special administrative regions, disputed territories and dependencies that are formally considering introducing certain spectrum bands for terrestrial 5G services, are holding consultations regarding suitable spectrum allocations for 5G, have reserved spectrum for 5G, have announced plans to auction frequencies or have already allocated spectrum for 5G use.[55] 5G devices In March 2019, the Global Mobile Suppliers Association released the industry's first database tracking worldwide 5G device launches.[56] In it, the GSA identified 23 vendors who have confirmed the availability of forthcoming 5G devices with 33 different devices including regional variants. There were seven announced 5G device form factors: (telephones (×12 devices), hotspots (×4), indoor and outdoor customer-premises equipment (×8), modules (×5), Snap-on dongles and adapters (×2), and USB terminals (×1)).[57] By October 2019, the number of announced 5G devices had risen to 129, across 15 form factors, from 56 vendors.[58] In the 5G IoT chipset arena, as of April 2019 there were four commercial 5G modem chipsets and one commercial processor/platform, with more launches expected in the near future.[59] On March 6, 2020, the first-ever all-5G smartphone Samsung Galaxy S20 was released. According to Business Insider, the 5G feature was showcased as more expensive in comparison with 4G; the line up starts at US$1,000, in comparison with Samsung Galaxy S10e which started at US$750.[60] On March 19, HMD Global, the current maker of Nokia-branded phones, announced the Nokia 8.3 5G, which it claimed as having a wider range of 5G compatibility than any other phone released to that time. The mid-range model, with an initial Eurozone price of €599, is claimed to support all 5G bands from 600 MHz to 3.8 GHz.[61] Many phone manufacturers support 5G. Apples iPhone 12 and later versions support 5G.[62][63] Googles Pixel phones support it, since version 5a.[64] Technology New radio frequencies See also: 5G NR frequency bands The air interface defined by 3GPP for 5G is known as New Radio (NR), and the specification is subdivided into two frequency bands, FR1 (below 6 GHz) and FR2 (24–54 GHz) Frequency range 1 (< 6 GHz) Otherwise known as sub-6, the maximum channel bandwidth defined for FR1 is 100 MHz, due to the scarcity of continuous spectrum in this crowded frequency range. The band most widely being used for 5G in this range is 3.3–4.2 GHz. The Korean carriers use the n78 band at 3.5 GHz. Some parties used the term "mid-band" frequency to refer to higher part of this frequency range that was not used in previous generations of mobile communication. Frequency range 2 (24–54 GHz) The minimum channel bandwidth defined for FR2 is 50 MHz and the maximum is 400 MHz, with two-channel aggregation supported in 3GPP Release 15. The higher the frequency, the greater the ability to support high data-transfer speeds. Signals in this frequency have been described as mmWave. FR2 coverage 5G in the 24 GHz range or above use higher frequencies than 4G, and as a result, some 5G signals are not capable of traveling large distances (over a few hundred meters), unlike 4G or lower frequency 5G signals (sub 6 GHz). This requires placing 5G base stations every few hundred meters in order to use higher frequency bands. Also, these higher frequency 5G signals cannot penetrate solid objects easily, such as cars, trees, and walls, because of the nature of these higher frequency electromagnetic waves. 5G cells can be deliberately designed to be as inconspicuous as possible, which finds applications in places like restaurants and shopping malls.[65] Cell types Deployment environment Max. number of users Output power (mW) Max. distance from base station 5G NR FR2 Femtocell Homes, businesses Home: 4–8Businesses: 16–32 indoors: 10–100outdoors: 200–1,000 tens of meters Pico cell Public areas like shopping malls,airports, train stations, skyscrapers 64 to 128 indoors: 100–250outdoors: 1,000–5,000 tens of meters Micro cell Urban areas to fill coverage gaps 128 to 256 outdoors: 5,000−10,000 few hundreds of meters Metro cell Urban areas to provide additional capacity more than 250 outdoors: 10,000−20,000 hundreds of meters Wi-Fi(for comparison) Homes, businesses fewer than 50 indoors: 20–100outdoors: 200–1,000 few tens of meters Massive MIMO See also: Multi-user MIMO MIMO systems use multiple antennas at the transmitter and receiver ends of a wireless communication system. Multiple antennas use the spatial dimension for multiplexing in addition to the time and frequency ones, without changing the bandwidth requirements of the system. Massive MIMO (multiple-input and multiple-output) antennas increases sector throughput and capacity density using large numbers of antennas. This includes Single User MIMO and Multi-user MIMO (MU-MIMO). Each antenna is individually-controlled and may embed radio transceiver components.[citation needed] Edge computing Main article: Multi-access edge computing Edge computing is delivered by computing servers closer to the ultimate user. It reduces latency and data traffic congestion.[66][67] Small cell Main article: Small cell Small cells are low-powered cellular radio access nodes that operate in licensed and unlicensed spectrum that have a range of 10 meters to a few kilometers. Small cells are critical to 5G networks, as 5G's radio waves can't travel long distances, because of 5G's higher frequencies.[68][69][70][71] Beamforming Main article: Beamforming There are two kinds of beamforming: digital and analog. Digital beamforming involves sending the data across multiple streams (layers), while analog beamforming shaping the radio waves to point in a specific direction. The analog BF technique combines the power from elements of the antenna array in such a way that signals at particular angles experience constructive interference, while other signals pointing to other angles experience destructive interference. This improves signal quality in the specific direction, as well as data transfer speeds.[citation needed] 5G uses both digital and analog beamforming to improve the system capacity.[citation needed] Convergence of Wi-Fi and cellular One expected benefit of the transition to 5G is the convergence of multiple networking functions to achieve cost, power, and complexity reductions. LTE has targeted convergence with Wi-Fi band/technology via various efforts, such as License Assisted Access (LAA; 5G signal in unlicensed frequency bands that are also used by Wi-Fi) and LTE-WLAN Aggregation (LWA; convergence with Wi-Fi Radio), but the differing capabilities of cellular and Wi-Fi have limited the scope of convergence. However, significant improvement in cellular performance specifications in 5G, combined with migration from Distributed Radio Access Network (D-RAN) to Cloud- or Centralized-RAN (C-RAN) and rollout of cellular small cells can potentially narrow the gap between Wi-Fi and cellular networks in dense and indoor deployments. Radio convergence could result in sharing ranging from the aggregation of cellular and Wi-Fi channels to the use of a single silicon device for multiple radio access technologies."Article - 5G ! Solwise Ltd". NOMA (non-orthogonal multiple access) NOMA (non-orthogonal multiple access) is a proposed multiple-access technique for future cellular systems via allocation of power.[citation needed] SDN/NFV Main articles: Software-defined networking, SD-WAN, Network function virtualization, and 5G network slicing Initially, cellular mobile communications technologies were designed in the context of providing voice services and Internet access. Today a new era of innovative tools and technologies is inclined towards developing a new pool of applications. This pool of applications consists of different domains such as the Internet of Things (IoT), web of connected autonomous vehicles, remotely controlled robots, and heterogeneous sensors connected to serve versatile applications.[72] In this context, network slicing has emerged as a key technology to efficiently embrace this new market model.[73] Channel coding The channel coding techniques for 5G NR have changed from Turbo codes in 4G to polar codes for the control channels and LDPC (low-density parity check codes) for the data channels.[74][75] Operation in unlicensed spectrum In December 2018, 3GPP began working on unlicensed spectrum specifications known as 5G NR-U, targeting 3GPP Release 16.[76] Qualcomm has made a similar proposal for LTE in unlicensed spectrum. Future evolution 5G-Advanced 5G-Advanced is a name for 3GPP release 18, which as of 2021[update] is under conceptual development.[77][78][79] Concerns Security concerns See also: Concerns over Chinese involvement in 5G wireless networks and Criticism of Huawei § Espionage and security concerns A report published by the European Commission and European Agency for Cybersecurity details the security issues surrounding 5G. The report warns against using a single supplier for a carrier's 5G infrastructure, especially those based outside the European Union. (Nokia and Ericsson are the only European manufacturers of 5G equipment.)[80] On October 18, 2018, a team of researchers from ETH Zurich, the University of Lorraine and the University of Dundee released a paper entitled, "A Formal Analysis of 5G Authentication".[81][82] It alerted that 5G technology could open ground for a new era of security threats. The paper described the technology as "immature and insufficiently tested," and one that "enables the movement and access of vastly higher quantities of data, and thus broadens attack surfaces". Simultaneously, network security companies such as Fortinet,[83] Arbor Networks,[84] A10 Networks,[85] and Voxility[86] advised on personalized and mixed security deployments against massive DDoS attacks foreseen after 5G deployment. IoT Analytics estimated an increase in the number of IoT devices, enabled by 5G technology, from 7 billion in 2018 to 21.5 billion by 2025.[87] This can raise the attack surface for these devices to a substantial scale, and the capacity for DDoS attacks, cryptojacking, and other cyberattacks could boost proportionally.[82] Due to fears of potential espionage of users of Chinese equipment vendors, several countries (including the United States, Australia and the United Kingdom as of early 2019)[88] have taken actions to restrict or eliminate the use of Chinese equipment in their respective 5G networks. Chinese vendors and the Chinese government have denied claims of espionage.[clarification needed] On 7 October 2020, the UK Parliament's Defence Committee released a report claiming that there was clear evidence of collusion between Huawei and Chinese state and the Chinese Communist Party. The UK Parliament's Defence Committee said that the government should consider removal of all Huawei equipment from its 5G networks earlier than planned.[89] Electromagnetic interference Weather forecasting Parts of this article (those related to Systems are turned on; is this happening?) need to be updated. Please help update this article to reflect recent events or newly available information. (January 2022) The spectrum used by various 5G proposals, especially the n258 band centered at 26 GHz, will be near that of passive remote sensing such as by weather and Earth observation satellites, particularly for water vapor monitoring at 23.8 GHz.[90] Interference is expected to occur due to such proximity and its effect could be significant without effective controls. An increase in interference already occurred with some other prior proximate band usages.[91][92] Interference to satellite operations impairs numerical weather prediction performance with substantially deleterious economic and public safety impacts in areas such as commercial aviation.[93][94] The concerns prompted U.S. Secretary of Commerce Wilbur Ross and NASA Administrator Jim Bridenstine in February 2019 to urge the FCC to delay some spectrum auction proposals, which was rejected.[95] The chairs of the House Appropriations Committee and House Science Committee wrote separate letters to FCC chairman Ajit Pai asking for further review and consultation with NOAA, NASA, and DoD, and warning of harmful impacts to national security.[96] Acting NOAA director Neil Jacobs testified before the House Committee in May 2019 that 5G out-of-band emissions could produce a 30% reduction in weather forecast accuracy and that the resulting degradation in ECMWF model performance would have resulted in failure to predict the track and thus the impact of Superstorm Sandy in 2012. The United States Navy in March 2019 wrote a memorandum warning of deterioration and made technical suggestions to control band bleed-over limits, for testing and fielding, and for coordination of the wireless industry and regulators with weather forecasting organizations.[97] At the 2019 quadrennial World Radiocommunication Conference (WRC), atmospheric scientists advocated for a strong buffer of −55 dBW, European regulators agreed on a recommendation of −42 dBW, and US regulators (the FCC) recommended a restriction of −20 dBW, which would permit signals 150 times stronger than the European proposal. The ITU decided on an intermediate −33 dBW until September 1, 2027 and after that a standard of −39 dBW.[98] This is closer to the European recommendation but even the delayed higher standard is much weaker than that pleaded for by atmospheric scientists, triggering warnings from the World Meteorological Organization (WMO) that the ITU standard, at 10 times less stringent than its recommendation, brings the "potential to significantly degrade the accuracy of data collected".[99] A representative of the American Meteorological Society (AMS) also warned of interference,[100] and the European Centre for Medium-Range Weather Forecasts (ECMWF), sternly warned, saying that society risks "history repeat[ing] itself" by ignoring atmospheric scientists' warnings (referencing global warming, monitoring of which could be imperiled).[101] In December 2019, a bipartisan request was sent from the US House Science Committee to the Government Accountability Office (GAO) to investigate why there is such a discrepancy between recommendations of US civilian and military science agencies and the regulator, the FCC.[102] Aviation The United States FAA has warned that radar altimeters on aircraft, which operate between 4.2 and 4.4 GHz, might be affected by 5G operations between 3.7 and 3.98 GHz. This is particularly an issue with older altimeters using RF filters[103] which lack protection from neighboring bands.[104] This is not as much of an issue in Europe, where 5G uses lower frequencies between 3.4 and 3.8 GHz.[105] Nonetheless, the DGAC in France has also expressed similar worries and recommended 5G phones be turned off or be put in airplane mode during flights.[106] On December 31, 2021, U.S. Transportation Secretary Pete Buttigieg and Steve Dickinson, administrator of the Federal Aviation Administration asked the chief executives of AT&T and Verizon to delay 5G implementation over aviation concerns. The government officials asked for a two-week delay starting on January 5, 2022 while investigations are conducted on the effects on radar altimeters. The government transportation officials also asked the cellular providers to hold off their new 5G service near 50 priority airports, to minimize disruption to air traffic that would be caused by some planes being disallowed from landing in poor visibility.[107] After coming to an agreement with government officials the day before,[108] Verizon and AT&T activated their 5G networks on January 19, 2022, except for certain towers near 50 airports.[109] AT&T scaled back its deployment even further than its agreement with the FAA required.[110] The FAA rushed to test and certify radar altimeters for interference so that planes could be allowed to perform instrument landings (e.g. at night and in low visibility) at affected airports. By January 16, it had certified equipment on 45% of the U.S. fleet, and 78% by January 20.[111] Airlines complained about the avoidable impact on their operations, and commentators said the affair called into question the competence of the FAA.[112] Several international airlines substituted different planes so they could avoid problems landing at scheduled airports, and about 2% of flights (320) were cancelled by the evening of January 19.[113] Further information: C band (IEEE) Satellite A number of 5G networks deployed on the radio frequency band of 3.3–3.6 GHz is expected to cause interference with C-Band satellite stations, which operate by receiving satellite signals at 3.4–4.2 GHz frequency.[114] This interference can be mitigated with low-noise block downconverters and waveguide filters.[114] Wi-Fi In regions like the US and EU, the 6 GHz band is to be opened up for unlicensed applications, which would permit the deployment of 5G-NR Unlicensed, 5G version of LTE in unlicensed spectrum, as well as Wi-Fi 6e. However, interference could occur with the co-existence of different standards in the frequency band.[115] Overhype There have been concerns surrounding the promotion of 5G, questioning whether the technology is overhyped. There are questions on whether 5G will truly change the customer experience,[116] ability for 5G's mmWave signal to provide significant coverage,[117][118] overstating what 5G can achieve or misattributing continuous technological improvement to "5G",[119] lack of new use case for carriers to profit from,[120] wrong focus on emphasizing direct benefits on individual consumers instead of for internet of things devices or solving the Last mile problem,[121] and overshadowing the possibility that in some aspects there might be other more appropriate technologies.[122] Such sort of concerns have also lead to consumers not trusting information provided by cellular providers on the topic.[123] Misinformation and controversy Main article: Misinformation related to 5G technology Health See also: Wireless device radiation and health There is a long history of fear and anxiety surrounding wireless signals that predates 5G technology. The fears about 5G are similar to those that have persisted throughout the 1990s and 2000s. They center on fringe claims that non-ionising radiation poses dangers to human health.[124] Unlike ionising radiation, non-ionizing radiation cannot remove electrons from atoms. The CDC says "Exposure to intense, direct amounts of non-ionizing radiation may result in damage to tissue due to heat. This is not common and mainly of concern in the workplace for those who work on large sources of non-ionizing radiation devices and instruments."[125] Some advocates of fringe health claim the regulatory standards are too low and influenced by lobbying groups.[124] Many popular books of dubious merit have been published on the subject including one by Joseph Mercola alleging that wireless technologies caused numerous conditions from ADHD to heart diseases and brain cancer. Mercola has drawn sharp criticism for his anti-vaccinationism during the COVID-19 pandemic and was warned by the FDA to stop selling fake COVID-19 cures through his online alternative medicine business.[124][126] According to the New York Times, one origin of the 5G health controversy was an erroneous unpublished study that physicist Bill P. Curry did for the Broward County School Board in 2000 which indicated that the absorption of external microwaves by brain tissue increased with frequency.[127] According to experts this was wrong, the millimeter waves used in 5G are safer than lower frequency microwaves because they cannot penetrate the skin and reach internal organs. Curry had confused in vitro and in vivo research. However Curry's study was widely distributed on the internet. Writing in The New York Times in 2019, William Broad reported that RT America began airing programming linking 5G to harmful health effects which "lack scientific support", such as "brain cancer, infertility, autism, heart tumors, and Alzheimer's disease". Broad asserted that the claims had increased. RT America had run seven programs on this theme by mid-April 2019 but only one in the whole of 2018. The network's coverage had spread to hundreds of blogs and websites.[128] In April 2019, the city of Brussels in Belgium blocked a 5G trial because of radiation rules.[129] In Geneva, Switzerland, a planned upgrade to 5G was stopped for the same reason.[130] The Swiss Telecommunications Association (ASUT) has said that studies have been unable to show that 5G frequencies have any health impact.[131] According to CNET,[132] "Members of Parliament in the Netherlands are also calling on the government to take a closer look at 5G. Several leaders in the United States Congress have written to the Federal Communications Commission expressing concern about potential health risks. In Mill Valley, California, the city council blocked the deployment of new 5G wireless cells."[132][133][134][135][136] Similar concerns were raised in Vermont[137] and New Hampshire.[132] The US FDA is quoted saying that it “continues to believe that the current safety limits for cellphone radiofrequency energy exposure remain acceptable for protecting the public health.”[138] After campaigning by activist groups, a series of small localities in the UK, including Totnes, Brighton and Hove, Glastonbury, and Frome, passed resolutions against the implementation of further 5G infrastructure, though these resolutions

have no impact on rollout plans.[139][140][141] COVID-19 conspiracy theories and arson attacks Main article: COVID-19 misinformation § 5G mobile-phone networks The World Health Organization published a mythbuster infographic to combat the conspiracy theories about COVID-19 and 5G. As the introduction of 5G technology coincided with the time of COVID-19 pandemic, several conspiracy theories circulating online posited a link between SARS-CoV-2 and 5G.[142] This has led to dozens of arson attacks being made on telecom masts in the Netherlands (Amsterdam, Rotterdam, etc.), Ireland (Cork,[143] etc.), Cyprus, the United Kingdom (Dagenham, Huddersfield, Birmingham, Belfast and Liverpool[144][145]), Belgium (Pelt), Italy (Maddaloni), Croatia (Bibinje[146]) and Sweden.[147] It led to at least 61 suspected arson attacks against telephone masts in the United Kingdom alone[148] and over twenty in The Netherlands. In the early months of the pandemic anti-lockdown protesters at protests over responses to the COVID-19 pandemic in Australia were seen with anti-5G signs, an early sign of what became a wider campaign by conspiracy theorists to link the pandemic with 5G technology. There are two versions of the 5G-COVID 19 conspiracy theory:[124] The first version claims that radiation weakens the immune system, making the body more vulnerable to SARS-CoV-2 (the virus that causes COVID-19). The second version claims that 5G causes COVID-19. There are different variations on this. Some claim that the pandemic is coverup of illness caused by 5G radiation or that COVID-19 originated in Wuhan because that city was "the guinea-pig city for 5G". Marketing of non-5G services Main articles: 5G Evolution, LTE Advanced Pro, and LTE Advanced In various parts of the world, carriers have launched numerous differently branded technologies, such as "5G Evolution", which advertise improving existing networks with the use of "5G technology".[149] However, these pre-5G networks are an improvement on specifications of existing LTE networks that are not exclusive to 5G. While the technology promises to deliver higher speeds, and is described by AT&T as a "foundation for our evolution to 5G while the 5G standards are being finalized," it cannot be considered to be true 5G. When AT&T announced 5G Evolution, 4x4 MIMO, the technology that AT&T is using to deliver the higher speeds, had already been put in place by T-Mobile without being branded with the 5G moniker. It is claimed that such branding is a marketing move that will cause confusion with consumers, as it is not made clear that such improvements are not true 5G.[150] History This section needs to be updated. Please help update this article to reflect recent events or newly available information. (April 2019) This article is in list format but may read better as prose. You can help by converting this article, if appropriate. Editing help is available. (March 2022) In April 2008, NASA partnered with Geoff Brown and Machine-to-Machine Intelligence (M2Mi) Corp to develop a fifth generation communications technology approach, though largely concerned with working with nanosats.[151] In 2008, the South Korean IT R&D program of "5G mobile communication systems based on beam-division multiple access and relays with group cooperation" was formed.[152] In August 2012, New York University founded NYU Wireless, a multi-disciplinary academic research centre that has conducted pioneering work in 5G wireless communications.[153] On October 8, 2012, the UK's University of Surrey secured £35M for a new 5G research centre, jointly funded by the British government's UK Research Partnership Investment Fund (UKRPIF) and a consortium of key international mobile operators and infrastructure providers, including Huawei, Samsung, Telefónica Europe, Fujitsu Laboratories Europe, Rohde & Schwarz, and Aircom International. It will offer testing facilities to mobile operators keen to develop a mobile standard that uses less energy and less radio spectrum, while delivering speeds higher than current 4G with aspirations for the new technology to be ready within a decade.[154][155][156][157] On November 1, 2012, the EU project "Mobile and wireless communications Enablers for the Twenty-twenty Information Society" (METIS) starts its activity toward the definition of 5G. METIS achieved an early global consensus on these systems. In this sense, METIS played an important role of building consensus among other external major stakeholders prior to global standardization activities. This was done by initiating and addressing work in relevant global fora (e.g. ITU-R), as well as in national and regional regulatory bodies.[158] Also in November 2012, the iJOIN EU project was launched, focusing on "small cell" technology, which is of key importance for taking advantage of limited and strategic resources, such as the radio wave spectrum. According to Günther Oettinger, the European Commissioner for Digital Economy and Society (2014–2019), "an innovative utilization of spectrum" is one of the key factors at the heart of 5G success. Oettinger further described it as "the essential resource for the wireless connectivity of which 5G will be the main driver".[159] iJOIN was selected by the European Commission as one of the pioneering 5G research projects to showcase early results on this technology at the Mobile World Congress 2015 (Barcelona, Spain). In February 2013, ITU-R Working Party 5D (WP 5D) started two study items: (1) Study on IMT Vision for 2020 and beyond, and; (2) Study on future technology trends for terrestrial IMT systems. Both aiming at having a better understanding of future technical aspects of mobile communications toward the definition of the next generation mobile.[160] On May 12, 2013, Samsung Electronics stated that they had developed a "5G" system. The core technology has a maximum speed of tens of Gbit/s (gigabits per second). In testing, the transfer speeds for the "5G" network sent data at 1.056 Gbit/s to a distance of up to 2 kilometers with the use of an 8*8 MIMO.[161][162] In July 2013, India and Israel agreed to work jointly on development of fifth generation (5G) telecom technologies.[163] On October 1, 2013, NTT (Nippon Telegraph and Telephone), the same company to launch world's first 5G network in Japan, wins Minister of Internal Affairs and Communications Award at CEATEC for 5G R&D efforts.[164] On November 6, 2013, Huawei announced plans to invest a minimum of $600 million into R&D for next generation 5G networks capable of speeds 100 times higher than modern LTE networks.[165] On April 3, 2019, South Korea became the first country to adopt 5G.[166] Just hours later, Verizon launched its 5G services in the United States, and disputed South Korea's claim of becoming the world's first country with a 5G network, because allegedly, South Korea's 5G service was launched initially for just six South Korean celebrities so that South Korea could claim the title of having the world's first 5G network.[167] In fact, the three main South Korean telecommunication companies (SK Telecom, KT, and LG Uplus) added more than 40,000 users to their 5G network on the launch day.[168] In June 2019, the Philippines became the first country in Southeast Asia to roll out a 5G network after Globe Telecom commercially launched its 5G data plans to customers.[169] AT&T brings 5G service to consumers and businesses in December 2019 ahead of plans to offer 5G throughout the United States in the first half of 2020.[170][171] Other applications Automobiles 5G Automotive Association have been promoting the C-V2X communication technology that will first be deployed in 4G. It provides for communication between vehicles and infrastructures.[172] Digital Twins A real time digital twin of the real object such as a turbine engine, aircraft, wind turbines, offshore platform and pipelines. 5G networks helps[173] in building it due to the latency and throughput to capture near real-time IoT data and support digital twins.[174] Public safety Mission-critical push-to-talk (MCPTT) and mission-critical video and data are expected to be furthered in 5G.[175] Fixed wireless Fixed wireless connections will offer an alternative to fixed line broadband (ADSL, VDSL, Fiber optic, and DOCSIS connections) in some locations.[176][177][178] Wireless video transmission for broadcast applications Sony has tested the possibility of using local 5G networks to replace the SDI cables currently used in broadcast camcorders.[179] The 5G Broadcast tests started around 2020 (Orkneys, Bavaria, Austria, Central Bohemia) based on FeMBMS (Further evolved multimedia broadcast multicast service).[180] The aim is to serve unlimited number of mobile or fixed devices with video (TV) and audio (radio) streams without these consuming any data flow or even being authenticated in a network. 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